EFFECT OF DOSAGE AND DURATION OF SULFURIC ACID ON DELINTING, SEED GERMINATION AND SEEDLING VIGOR OF COTTON (*Gossypium hirsutum* L.)

By

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The M.Sc. Thesis by Demelew Nebiyu entitled as **"Effect of Dosage and Duration of Sulfuric Acid on Delinting, Seed Germination and Seedling Vigor of Cotton (*Gossypium hirsutum* L.)"** submitted to postgraduate directorate for open defense as a fulfillment of Master's degree in Agronomy, Department of Plant Sciences, College of Agriculture and Rural Transformation, University of Gondar, Ethiopia.

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The author dedicated this thesis manuscript to his family.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born in 1969 G.C.in Dembecha Gojjam Ethiopia. He attended elementary education at Dembecha Elementary and Junior Secondary School from 1975 to 1982. He completed his Senior Secondary School Education at Bahir Dar Tana Hike in 1986. In 1987, he joined Jimma College of Agriculture and graduated with diploma in general agriculture in 1988. After a long time service in the Ministry of Agriculture, in 2002 he joined Jimma University summer program and graduated his BSc degree in Horticulture in 2006. He served in ministry of agriculture in different capacities (Agronomist, Agricultural Extension Team Leader, Irrigation Agronomy Team Leader, Seed Quality Inspector and Seed Quarantine and Seed Quality Coordinator). In 2014, the author joined the School of Graduate Studies at the University of Gondar to pursuit his MSc Degree in Agronomy. He is married and has two children.

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ACRONYMS AND ABBREVIATIONS

ADLI	Agriculture Development Led-Industrialization
ANOVA	Analysis of Variance
AS	Abnormal Seedling
CRD	Completely Randomized Design
DFS	Dry weight of fuzzy seed
DWDS	Dry weight of delinted seed
DWLCDS	Dry weight of last constant delinted seed
EC	Ethiopian Calendar
FGP	Final Germination Percentage
GE	Germination Efficiency
GR	Germination Rate
GS	Germination Speed
GSI	Germination Speed Index
ISTA	International Seed Testing Association
LSD	Least Significant Difference
MTG	Mean Time Germination
NCPA	National Cotton Products Association
NS	Normal Seedling
RL	Root Length
SAE	Sulfuric Acid Efficiency
SDW	Seedling Dry Weight
SL	Shoot Length
SG	Speed of Germination
SVI-I	Seedling Vigor Index-I
SVI-II	Seedling Vigor Index-II

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Effect of Dosage and Duration of Sulfuric Acid on Delinting, Seed Germination and Seedling Vigor of Cotton (*Gossypium hirsutum* L.)

By

Demelew Nebiyu Antneh

ABSTRACT

In order to study the effect of sulfuric acid amount/volume and duration of delinting on germination and seedling vigor of cotton (*Gossypium hirsutum* L.) seeds, experiments were conducted in completely randomized design with twenty one treatments in four replications at the Gondar Seed Laboratory during 2016. The treatments consisted of one kg of fuzzy cotton seeds of variety Deltapine-90 for each treatment for delinting by five different quantities/volumes of 98% concentrated sulfuric acid (60mL, 90mL, 120mL, 150mL and 180mL/kg) incubated for four different delinting durations, i.e. 4min, 8min, 12min and 16min,respectively. Fuzzy cotton seeds served as control treatment (untreated). The results revealed that both the amount of sulfuric acid and delinting duration had significant effect on lint-removing efficiency, germination percentage, mean germination time, germination speed and seed vigor were increased with increase in acid and contact time to certain level and then started declining. Sulfuric acid-delinting efficiency was positively and highly significantly correlated with the amount and delinting duration. Visual observations revealed that some seeds did freely flow when treated with 90mL of sulfuric acid delinted for 8min (35.9%) whose numbers increased (100%) when delinted by 180mL for 16min. All the seed treatments improved final germination percentage with significant differences among treatments as compared to control. The maximum germination (94%), normal seedling (88.7%), maximum seedling weight, roots and shoot length were all observed on account of delinting by 150mL of sulfuric acid treated for 12min.It is therefore, concluded that removing lint by using optimum amount of sulfuric acid for appropriate delinting duration can improve free flow of seeds during sowing, germination efficiency, enhance speed of germination and seedling vigor of planting cotton seeds However, as the study was conducted only for one time, it should be repeated using the same or modified treatments to arrive at concrete recommendation.

Keywords: *Fuzzy cotton seed, delinted seed, sulfuric acid, germination efficiency, seedling vigor.*

1. INTRODUCTION

1.1. Background and Justification

Cotton species (*Gossypium*) belong to the Malvaceae family (like Okra and Hibiscus). Their wild relatives are hardy perennial shrubs with hairy leaves and short fibers. Cotton can be described as a soft, downy substance, resembling fine wool, which grows on the seeds of the cotton plant. It is also described as a soft, fluffy staple fibre that grows in a boll, or protective capsule, around the seeds of cotton plants. The fibre is usually spun into yarn or thread and used to make a soft, breathable textile. Some specific examples of the products in which cotton is used include oils, balls, swabs, bandages, tissue, paper, napkins, diapers, socks, underwear, shirts, shorts, sweaters, pants, coats, towels, linen, cushions, drapery, upholstery, rugs, carpet, comforters, mattresses, insulation, filtration. There are various other things – people wear, people sleep on, people sleep under, people walk on and utilize in would care – used daily by human beings which are composed of cotton (Smith *et al.,* 1999).

It is known as a natural fibre and is used in a variety of ways. Cotton fibre can be long (about 2 inches) staple; as well as short (from two thirds of an inch to an inch and a half) staple. In the recent periods, some other classifications of cotton have also emerged. Presently, there are four commercially-grown species of cotton, all domesticated long back. While two of these evolved in the New World, other two evolved in the Old World (Norton *et al.,* 2007). These include:

New world cotton

• Gossypium hirsutum – upland cotton, native to Central America, Mexico, the Caribbean and southern Florida. This constitutes about 90 percent of world production of cotton.

• Gossypium barbadense – This is known for its extra-long staple feature. It is a native to tropical South America, and constitutes 8 percent of world cotton production.

Old World cotton

• Gossypium arboreum – This is a native to India and Pakistan. This constitutes less than 2 percent of world cotton production.

• Gossypium herbaceum – This is a native to southern Africa and the Arabian Peninsula and constitutes less than 2 percent of world production.

The two New World cotton species have gained prominence in the twentieth century. These now account for the vast majority of modern cotton production. The two Old World species were widely used before the 1900s (Foulk *et al.,* 2003).

Cotton fibers occur naturally in colors of white, brown, pink, and green but fears of contaminating the genetics of white cotton have led many cotton-growing locations to ban the growing of colored cotton varieties, which still remain a specialty product (Goreux, 2003).

Cotton is grown in a wide range of climatic conditions in temperate, subtropical and tropical regions of all the continents. Ideal conditions are in regions with long vegetation periods without frost, high temperature (ideally around 30°C), ample sunshine, and a rather dry climate. It requires a minimum of 500 mm water from rain or irrigation between germination to boll formation. Cotton is very sensitive to water-logging which causes a reduction in yields (more boll shedding) even when the plant appears to be unaffected. It prefers deep, well-drained soils with a good nutrient content (Soomro *et al*., 2001). The clay-rich vertisols (so-called 'black cotton soils') are ideal. With their long tap roots penetrating up to three meters in such soils, cotton plants can sustain short periods of drought. However, cotton is also grown on less ideal sites with shallow, sandy soils, both under irrigated and rain-fed conditions. This requires the selection of adaptable varieties and required management practices.

Cotton is the most valuable fiber crop in the world. It accounts for more than half of all fibers used in clothing and household furnishings (Akiyama *et al.,* 2003). For long, cotton has maintained a significant place in the economic and political history of the world and it has played an immense role since the industrial revolution of the17th century. It is an important source of cash for the growers and raw material for the textile industries, village handloom industries and oil extracting mills; generates employment opportunities in agriculture and industry, and earns significant amount of foreign currency by exporting lint and textile fabrics. The residual obtained after oil extracting could be used as animal feed and organic fertilizer, and the stalk after harvesting the seed cotton is used for fencing and as a raw material for making charcoal (energy sources) to small-scale farmers (Salunkhe *et al.,* 1992).

Currently, it is an important cash crop for a number of developing countries at farm and national levels (Akiyama *et al*., 2001). Commercial cotton production in Ethiopia was started after World War II with the introduction of exotic cotton species (*Gossypium hirsutum*). Cotton played an important role as a means of livelihood for craftsmen involved in the weaving cottage industry and has been contributing a lot to the development of textile industries (Mayee and Rao, 2002). Ethiopia has a long tradition of cotton cultivation with 2.6 million hectares of land suitable for cotton production which is equivalent to that of Pakistan's cotton area (a top-10 global producer) but representing only 3% of land under cultivation (CSA, 2011). Ethiopia has formally adopted

Agricultural Development-Led Industrialization (ADLI) as its development strategy and the current annual production of seed cotton is approximately 120,000 tons with an overall average yield of 1.42 tons/hectare which is below the world productivity per hectare (CSA, 2011).However, Ethiopia has the potential to become a major global cotton producer but presently cotton industry is far behind to the level obtained in 2010. Meantime, consumption is forecast to grow domestic cotton production in large part of the country due to the demands of the rapidly-expanding textile/apparel industry. These expected enhancements are primarily attributed to the gradual expansion in the acreage of land planted in cotton, which is currently estimated at 130,000 to 135,000 hectares (CSA, 2011). The country's main cotton production areas are located in the semi-arid lowlands of Ethiopia; with majority of its cultivation in the Awash Valley, with some cultivation in Gambela and Humera as well. In Amhara region, the western parts of lowland areas mainly north Gondar zone; Quara, Metema, Tsgdie, Tach-Armachiho and West Armachiho districts are the main ideal places for cotton production.

Cotton seed is naturally covered by lints and such type of seed is called fuzzy seed. These cotton fibers are called "lint". The linters that remain on cottonseed after ginning become entangled, causing the seed to clump. Since gin-run seeds do not singulate and the flow ability is very poor, the presence of fuzz on cotton seeds causes hindrance in operations like processing, sowing etc. The traditional way of sowing fuzzy seeds by small holder farmers is separating each seed by their hand. This practice is tedious and inappropriate for modern agricultural system. Lint-free seeds can more precisely pass through the cotton planter and generally lead to a more economical planting. Lint-free seeds can be more precisely planted and grow much sooner less than half the time required for fuzzy seeds (Chowdhury, 1997). The effective method used for delinting fuzzy seeds is the use of sulfuric acid. In acid delinting, the seed recovery however, decreased with the increase in the dosage of sulfuric acid (H_2SO_4) in effort to have complete removal of fuzz from seed coat by the higher doses of the acid (Shivayogi *et al.,* 2006). The dosage and duration of acid treatment for delinting fuzzy cotton seeds is therefore, important from view point of its effectiveness. The amount and duration of sulfuric acid for delinting fuzzy seeds of Deltapine-90 cotton variety which is grown widely is not yet studied in our country. So, this research thesis focuses on the effective amount and duration of sulfuric acid treatment for delinting fuzzy cotton seeds, germination and seedling vigor.

1.2. Statement of the Problem

In Ethiopia cotton productivity per hectare is very low as compared to other cotton growing countries of the world. It is partly due to poor agronomic practices like appropriate time of sowing which is believed to be one of the most important factors responsible for yield performance. The limited availability of quality inputs, including seeds restricted the potential expansion of cotton production. Nowadays in Ethiopia small holder farmers and investors are changing their farming system, i.e. from sesame to cotton production because of increased domestic demand of cotton fibers and decreased world market for sesame. Textile factories need quality lint suited to their standard of color, strength, length, etc of fiber. Investors and farmers must get such improved quality seed to produce appropriate cotton fibers. Fuzz on cotton apart from reducing the seed germination due to low moisture absorption by seed resulting in a poor plant stand (Patil and Andrews, 1985). It is difficult to remove the damaged, diseased and immature seeds during grading, which results in poor germination.

Most cotton producers prefer lint-free, naked cotton planting seed. Lint-free seeds can be more precisely metered through the cotton planter and generally lead to a more economical planting. Lint-free seeds can be more precisely planted which grow much sooner as well (less than half the time required for fuzzy seeds). Therefore, lint-free seeds are preferable for sowing. The effective method used for delinting fuzzy seeds is the use of sulfuric acid. However, due to acid-delinting the seed recovery is decreased with the increase in the dosage of sulfuric acid in efforts to obtaining complete removal of fuzz from seed coat by the higher doses of the acid (Shivayogi *et al.,* 2006). Higher doses of H_2SO_4 reduce the seed quality because of their adverse effect on seed coat leading to depletion in seed nutrients, apart from killing the embryo itself (Swaminathan *et al*., 1974). Further increase or decrease in dosage of H_2SO_4 than the optimum one reduces seed germination. The decrease in germination and other seed quality parameters with lower concentration of H_2SO_4 is often due to the incomplete removal of fuzz from the seed coat which, in turn, would slow down the seed germination and seedling growth because of low absorption of moisture by the seed coat (Patil and Andrews, 1985). Because of this, it is necessary to evaluate the effect of dosage and duration of sulfuric acid treatment on delinting fuzzy seeds which is expected to impact seed germination and seedling vigor.

1.3. Significance of the Study

Using quality seeds is a fundamental yield-enhancing input for sustainable growth in agriculture. Cotton seed is fully covered with fibrous lint (Thaxton and El-Zik, 2001) and once ginned; the cotton seed still remains covered with linters and called as whole cotton seed or fuzzy cotton seed. The amount of linters left on the seeds varies from 8 to 10% (Mayee, C.D. and M.R.K. Rao, 2002). Fuzzy cotton seeds are subject to a mechanical delinting process that yields linters and naked seeds called as delinted cottonseed or black or slick cotton seed (Hoffman, 2002). Cotton seeds intended for sowing generally undergo chemical treatment in order to remove linters. Very often acid delinting damages the seed coat and hence there is a need to standardize concentration and duration of delinting without affecting the seed quality.

The amount and duration of chemical treatment that is used in order to delint fuzzy cotton seeds are not yet studied in Ethiopia. As the textile industries grow in number, the sector would need more raw materials of cotton fibers. So, both the production and productivity of cotton must go side by side. The agriculture sector must deliver improved delinted seeds to small holder farmers and investors for easy and effective sowing by using modern planting equipment. Knowing the amount or volume of sulfuric acid and delinting duration for fuzzy cotton seeds is therefore, important to minimize the undesirable effect of either over-or under-dose of sulfuric acid on seed germination and seedling vigor in order to practices cost-effective cotton cultivation.

1.4. Objective of the Study

1.4.1. General objective

The present study is conducted with the main objective of evaluating the effect dosage of sulfuric acid and duration on delinting, seed germination and seedling vigor of cotton.

1.4.2. Specific objectives

- To determine the appropriate amount/volume of sulfuric acid for delinting fuzzy cotton seeds for better germination and seedling vigor.
- To determine the appropriate delinting duration for fuzzy cotton seeds.
- To compare and contrast the seed germination process and seedling vigor between fuzzy seeds and those of delinted seeds.

1.5. Research Questions to be Addressed

- ✓ What amount (concentration) of sulfuric acid is needed for delinting of fuzzy cotton seeds?
- ✓ How long the fuzzy cotton seeds should soaked in sulfuric acid for complete removal of fuzz?
- ✓ What is the effect of delinting on seed germination and seedling vigor?

2. LITERATURE REVIEW

2.1. Concept of Removing Lint from Cotton Seed before Sowing

Cotton has been grown for its fiber for several thousands of years. Its cultivation and manufacture into cloth developed independently in both the Eastern and Western Hemispheres. One of the oldest records of cotton textiles dating back to about 5,000 years was found in the Indus River Valley what is now in Pakistan. Excavations in Peru and Mexico have uncovered cotton cloth identified as being 4,500 to 7,000 years old. Cotton fabrics have also been found in the remains of some of the ancient civilizations of Egypt and in the ruins of Indian pueblos of the south-western United States, dating back to hundreds of years before Christ. The desire for cotton and cotton fabrics was one of the factors that led to European explorations during the 15th and 16th centuries when Columbus reached the West Indies where he found cotton growing and the natives wearing cotton cloth. This was part of the evidence that led him to believe that he had reached India (Xu and Watson, 1999).

Cotton bolls are made up of 4 to 5 locks. Each lock contains approximately 7 seeds to which the lint is tightly attached. When fully mature, these bolls dry out and fluff open to give the characteristic look of a field of white cotton ready to pick (Barker *et al*., 1995).Cottonseed, as the by-product of cotton ginning operation, is covered with fibrous lint. The cottonseed is mainly made of inner kernel, usually called "meats". This meaty portion contains all the oil as well as proteins, and it is enclosed in the fibrous hull. The cotton seeds obtained from ginneries contain about 8 to 10% of lint (fuzz), which makes them tangled together during sowing (Gregory and Savoy, 1999). These cotton fibers are called "lint". The linters that remain on cottonseed after ginning become entangled, causing the seeds to clump. Since gin-run seeds do not singulate and the flow ability is very poor, cleaning, upgrading and accurate metering in planting operations are difficult to impossible. Presence of fuzz on the seed coat of cotton makes it difficult to remove the damaged, diseased and immature seeds during grading, which results in poor germination. The presence of fuzz also causes hindrance in operations like processing, sowing etc., apart from reducing the seed germination due to low moisture absorption by seed resulting in a poor plant stand (Patil and Andrews, 1985). Removal of fuzz from the cotton seeds is therefore, necessary in order to improve the planting value of the seeds. There are different methods of removing linters from fuzzy cotton seeds.

2.2. Fuzzy Seed

Fuzzy seeds are the cottonseeds after the textile ginneries have removed the lint from the seeds having some fibers still attached to them. However, the best seeds should be selected to be used as planting material for the next season's cotton crop. Seed selection with fuzz on seeds is difficult at best. The residual lint on fuzzy seeds tangles and inhibits flow. This limits the cleaning and grading that are otherwise possible. Residual lint makes thorough cleaning, conditioning and treating operations impossible. High planting rates are required because fuzzy seeds do not readily flow through modern equipment Boyd, A.H., ., 1987.

2.3. Delinting

Delinting is a process which completely removes all linters affected by different methods. Delinted seed is free flowing which makes easy for mechanical cleaning, upgrading, treating and packing. The importance of having cottonseed that will flow in a singulated manner has increased through the years with the development of modern planting equipment. Various methods have been and are being used to remove linters from the seed and improve flow ability. Most of the methods involve partial or complete removal of the linters and tags, but a variety of coating procedures have also been tried without much success, technically or economically (Murti and Achaya, 1975).

2.3.1. Mechanical delinting

Mechanical delinting is basically used with finer and more closely-spaced saws to remove a portion of the linters, which have commercial value. Mechanical delinting improves flow ability of the seed, but not sufficiently for the precision conditioning operations required to separate despined cockleburs and immature, low density seeds (Becker and Wedegaertner, 2001). Plantability is also improved, but precision of metering is less than for smooth, readily flowable seed. The major effect of mechanical delinting on seed quality other than improvement of flow ability is mechanical damage. The mechanical delinting is more laborious and time-consuming (Swaminathan *et al.,* 1974). Mechanically delinted seed retains about 1-2% residual linters which usually appear on the ends of the seeds. The limitations of mechanical delinting in terms of improvement in flow ability led to the development of supplemental or other methods for partial or complete removal of the linters.

2.3.2. Chemical delinting

2.3.2.1. Wet sulfuric acid delinting

Sulfuric acid is manufactured by burning sulfur or some other metallic sulfide in oxygen or air followed by the oxidation of sulfur dioxide (SO_2) with air or oxygen to sulfur trioxide (SO_3), and the reaction of the sulfur trioxide with water leads to the formation of sulfuric acid (H_2SO_4). Acid delinting is a process that is commonly practiced by treating seeds with concentrated acids or gases besides mechanically removing the lint (Hiwase *et al*., 1994). The gas (fume) delinting presently is not being used practically as large quantities of seeds are required each time. Hence, acid delinting with H_2SO_4 is commonly used for delinting of cotton seeds on commercial scale. It is the process of exposing fuzzy cotton seeds to a wet sulfuric acid (H_2SO_4) solution (Cherry and Leffler, 1984;). Acid delinting is a process that completely removes all linters and therefore, it is used for the production of planting seeds. Delinting facilitates separation of immature, insect-and disease-affected seeds, thus upgrading thereby the seed quality as well (Olivier, 2005). In addition, this process aids in the flow ability of the seeds through air and vacuum planters. The acid delinting process removes the residual lint leaving each seed smooth and compatible with not only the cleaning and conditioning equipment but it also flows easily through modern planting machines. Once the residual fuzz is removed, the undesirable materials such as sticks, foreign particles and trash can easily be separated from the seed stock. Further separation is then made according to density which eliminates the immature seeds (Delouche, 1986).

2.3.2.2. Dry hydrochloric acid (HCl) gas delinting

In the process of acid delinting huge quantities of water with acid is let out after several washings of the seeds in the open which causes health hazards and environmental pollution. Hence, an alternative method known as dry gas delinting was evolved which has gained importance in the recent years (Hiwase *et al*., 1994). In dry gas delinting, dry HCl gas is injected in revolving drum containing fuzzy seeds. The drum is heated by using burners so that seed temperature reaches to 49^{o}C and hydrolysis takes place. The hydrolyzed lint gets broken in a scalper. Use of ammonia gas neutralizes the acid traces. However, gas-acid process using anhydrous hydrochloric acid is very dangerous for human health (Olivier *et al*., 2002).

3. MATERIALS AND METHODS

3.1. Description of Experimental Site

The laboratory experiment was conducted in Gondar Seed Laboratory during 2016. Gondar is situated in north-western Ethiopia, 738km North-West of Addis Ababa and has a latitude and longitude of $12^{\circ}36'$N and $37^{\circ}28'$E, respectively having an elevation of 2133 masl.

3.2. Experimental Materials and Treatments

A fuzzy seeds of improved cotton variety Deltapine 90, which is under production in cotton growing area of Ethiopia, were used as experimental material. The seeds produced by farmers in Metema which is located 120 km west of Gondar, during 2015 production year and ginned by Triet ginner factory were procured. Seed-delinting material, 98% sulfuric acid (H_2SO_4), fuzzy cotton seeds, tap water, sand, growing plastic bowl, digital balance, oven, meter, ruler, spoon and forceps were used for conducting the experiments.

Table 1. Details of treatments

Treatment code	Treatment combinations
T_1	Untreated seed(fuzzy seed)
T_2	60mL H_2SO_4 for 1kg of fuzzy seed delinting for 4min
T_3	60mL H_2SO_4 for 1kg of fuzzy seed delinting for 8min
T_4	60mLH_2SO_4 for 1kg of fuzzy seed delinting for 12min
T_5	60mL H_2SO_4 for 1kg of fuzzy seed delinting for 16min
T_6	90mL H_2SO_4 for 1kg of fuzzy seed delinting for 4min
T_7	90mL H_2SO_4 for 1kg of fuzzy seed delinting for 8min
T_8	90mL H_2SO_4 for 1kg of fuzzy seed delinting for 12min
T_9	90mL H_2SO_4 for 1kg of fuzzy seed delinting for 16min
T_{10}	120mL H_2SO_4 for 1kg of fuzzy seed delinting for 4min
T_{11}	120mL H_2SO_4 for 1kg of fuzzy seed delinting for 8min
T_{12}	120mL H_2SO_4 for 1kg of fuzzy seed delinting for 12min
T_{13}	120mL H_2SO_4 for 1kg of fuzzy seed delinting for 16min
T_{14}	150mL H_2SO_4 for 1kg of fuzzy seed delinting for 4min
T_{15}	150mL H_2SO_4 for 1kg of fuzzy seed delinting for 8min
T_{16}	150mL H_2SO_4 for 1kg of fuzzy seed delinting for 12min
T_{17}	150mL H_2SO_4 for 1kg of fuzzy seed delinting for 16min
T_{18}	180mL H_2SO_4 for 1kg of fuzzy seed delinting for 4min
T_{19}	180mL H_2SO_4 for 1kg of fuzzy seed delinting for 8min
T_{20}	180mL H_2SO_4 for 1kg of fuzzy seed delinting for 12min
T_{21}	180mL H_2SO_4 for 1kg of fuzzy seed delinting for 16min

3.3. Experimental Design and Procedures

The experiment was laid out in completely randomized design (CRD) consisting of twenty one treatment combinations with four replications. Fuzzy cotton seeds from ginner factory were taken after thoroughly mixing the seeds. After weighing one kg of fuzzy seeds for each treatment different quantities of 98% concentrated sulfuric acid, i.e. 60, 90, 120, 150 and 180mL/kg of fuzzy seeds were stirred in the pot with seeds using long stick and left for delinting periods of 4, 8, 12 and 16 minutes, respectively. Once the time was over, these seeds were washed three times using tap water in order to avoid H_2SO_4. After final washing the lighter seeds were removed by water flotation method and the good seeds (sinkers) were dried under sun. After drying for 4hrs, seed germination tests were carried out under laboratory condition having room temperature around 25^0C. Seed samples having 100 pure seeds for each treatment were randomly counted after thoroughly mixing the sample using spoon. Treatments were replicated four times and seeds were placed on germination bowls having sterilized sand moistened by distilled water in the ratio of 160mL of water to 1kg of sand (ISTA, 1999). Treatment combinations consisting of seeds having been delinted for different durations and levels of H_2SO_4 were arranged in completely randomized design (CRD) for germination and seedling vigor tests. Afterwards, collection of data was commenced and continued until 12 days when the final germination was complete and seedling vigor evaluated.

3.4. Preparing Sowing Media and Delinting Processes

Delinting is the process of removal of fuzz from the seed coat in cotton, i.e. it is a crop- specific seed management technique.

A. One kg of fuzzy cotton seeds was taken in a plastic bucket.
B. H_2SO_4 at the rate of required volume (mL) were added to one kg of seeds.
C. While adding H_2SO_4, it was constantly stirred by wooden stick for required period of time to facilitate and ensure uniform coverage of mixing with fuzzy seeds.
D. After these operations, seeds turned into coffee brown color and seeds were then washed immediately three times with cold water until the acid nature of the seeds stood removed.
E. After thorough washing, the entire seed lots, separately as per treatments, were placed in water in 1:10 (seed: water) ratio to remove floaters, if any.
F. The sinker seeds to be used for sowing were dried under sun for 4hrs.

3.5. Data Collection

Data on delinting efficiency of sulfuric acid following acid treatment, germination efficiency, speed of germination and seedling vigor were recorded after the laboratory experiments which are described below.

3.5.1. Delinting efficiency of sulfuric acid

Efficiency of sulfuric acid for the removal of lint from cotton seeds was evaluated first. For this, samples of 100g oven-dried fuzzy seeds from each replication of each treatment separately were taken and then these samples were treated with sulfuric acid as per treatment combinations given in Table 1. After the treatment periods were over, samples were dried separately at 103±2°C for 16 hrs. At the end, the containers having these seeds were placed in desiccators to cool the samples for 25-30min and after cooling the samples were weighed by electronic digital balance. Subsequently, weight of delinted seeds were recorded after complete removal of sulfuric acid from seeds following drying procedure outlined above. Delinting efficiency was calculated by adopting the formula developed by (Dogan et al., 2003).

$$\text{DelintingEfficiency}(\%) = \frac{\text{DFS} - \text{DWDS}}{\text{DFS} - \text{DWLCDS}} \text{X } 100$$

Where, DFS = Dry weight of fuzzy seeds,

DWDS = Dry weight of delinted seeds

DWLCDS = Dry weight of last constant delinted seeds

3.5.2. Germination testing systems

a. Germination efficiency index

Germination is generally associated with emergence of the radicle through the seed coat. The International Seed Testing Association (ISTA 2004) defines germination as "the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether it is able to develop further into a satisfactory plant under favourable conditions". According to international seed testing association (ISTA, 1999) four replications of hundred seeds each were sown in the growing bowls having moistened sands with a proportion of 160mL distilled water for 1kg sands and kept under the test conditions of 25±1°C in a germination room. After 12 days, the normal seedlings were counted. Normal seedlings were defined as those having visibly developed into healthy plantlets. Germination test results were classified into four major categories, i.e. normal seedlings, abnormal seedlings, fresh seeds, hard seeds and dead seeds.

- Normal seedlings: - that possess essential structures that are indicative of their ability to produce useful mature plants under favorable field conditions.

- Abnormal Seedlings: - that exhibit some form of growth, but have insufficient plant structures to maintain a healthy plant, such as missing roots or shoots.
- Fresh Seeds: - Seeds that have failed to germinate but have imbibed water. They appear firm, fresh and capable of germination, but remain dormant.
- Hard Seeds. Seeds that remains hard at the end of the prescribed test period, because their seed coats are impermeable to water.
- Dead Seeds: - Seeds that cannot produce any part of a seedling.

Final germination percentage was calculated at the end of experiment. Germination efficiency was judged by germination percentage which was calculated based on the average of the four replications of 100 seeds each (ISTA, 1996):

$$\text{Germination efficiency}(\%) = \frac{\text{Total number of normal seedlings}}{\text{Total number of seeds planted}} X\ 100$$

b. Germination speed *indexes*

Seed germination process was studied on daily basis for 12 days. Parameters including mean germination time (MGT) and germination rate or germination index (GI) were employed to evaluate the germination speed.

i. Germination speed index-I

In the germination speed index, maximum weight is given to the seeds germinated on the first day and less to those germinated later on. The lowest weight would be for seeds germinated on the 12th day. Therefore, the germination speed index emphasizes on both the percentage of germination and its speed. A higher germination speed index value denotes a higher percentage and rate of germination was calculated by. (Bench *et al*., 1991):

$$GI = (12\times n1) + (11\times n2) + \cdot\cdot\cdot + (1\times n12)$$

Where, n1, n2 . . . n112 = No. of germinated seeds on the first, second and subsequent days until the 12th day; 12, 11 . . . and 1 are weights given to the number of germinated seeds on the first, second and subsequent days, respectively n= number of seeds germinated on day D, D= number of day(s) counted from the beginning of germination, ∑n= total number of germinated seeds.

ii. Germination rate index-II

Germination rate index /GRI/ reflects the percentage of germination on each day of the germination period. Higher GRI values indicate higher and faster germination (Craufurd *et al.* ,1994). Germination rate index was calculated as described in the Association of Official Seed Analysts (AOSA, 1983) using the following formula:

$$\text{GRI} = \sum \frac{GT1}{T1} + \cdots + \frac{GTn}{Tn}$$

Where, GT is the number of seeds germinated each day and T refers to the experimental days.

3.5.2.1. Seedling vigor testing

Seedling vigor tests included inclusive length of shoot and root seedlings, and the dry weight of seedlings (root + shoot) (ISTA, 1996).

a. Seedling vigor index-I

Root and shoot lengths were measured at 12^{th} day of sowing after standard germination test. Ten normal seedlings were taken randomly from each replication of delinted and fuzzy seeds (control). The length between the collar and tip of the primary root was defined as root length and the mean length expressed in centimeter. Similarly, the same ten seedlings used for measuring the root length, were utilized for measuring the shoot length. The length between collar and tip of the primary shoot constituted the shoot length. Seedling vigor index-I (SVI-I) based on shoot and root length was calculated by adopting the formula developed by (Abdul-Baki, 1973):

$$\text{SVI-I} = \text{Mean seedling length (cm)} \times \text{Germination (\%)}$$

b. Seedling vigor index-II

Seedling dry weight is another method of expressing seedling vigor. The seedling dry weight was recorded after the final count in the standard germination test. Ten normal seedlings from the germination test were selected at random, dried in a hot air oven maintained at 85°C for 48 hrs, then cooled in desiccators for 30min and finally weighed using an electronic digital balance (ICAC, 2002). Seedling vigor index-II (SVI-II) based on seedling dry weight (mg) was calculated in the following manner:

SVI-II = Mean seedling dry weight (mg) x Germination (%)

3.6. Data Analysis

Experimental data were subjected to Analysis of Variance (ANOVA) appropriate to the design of the experiment using SAS (version 9) software. Per the results of ANOVA, means separation was carried out using Least Significant Difference (LSD) at 1% or 5% probability levels.

4. RESULTS AND DISCUSSION

4.1. Delinting Efficiency of Sulfuric Acid

The experiment was conducted with the main objectives of evaluating the effect of sulfuric acid dosage and duration on delinting, seed germination and seedling vigor of cotton variety Deltapine 90. In view of these, various parameters were measured and statistically analyzed. Efficiency of sulfuric acid based on amount and duration of delinting for the removal of lint from planting cotton seeds was first evaluated and the results are presented in Table 2. The analysis revealed highly significant differences ($P<0.01$) among various treatments with respect to the efficiency of removing lint from the fuzzy cotton seeds. Regarding mean values of results, the maximum delinting (100%) was achieved in seeds delinted with 180mL/1kg of sulfuric acid treated for 16min.

The minimum delinting (13.91%) was recorded in seeds delinted with 60mL/1kg of sulfuric acid for 4min with the remainder of treatments yielding intermediate results .Similar study conducted on cotton variety MCU 5 by (Singh *et al*. 1981) revealed that delinting by 200 mL/1kg of seeds ensures complete removal of lint from fuzzy cotton seeds. Delinting of Jayadhar cotton variety seeds treated with 90 mL of H_2SO_4 per kg for 8 minutes are ensures complete removal of lint from fuzzy cotton seeds (NCPA, 2012). The results indicates that delinting efficiency depend on cotton variety and dosage of H_2SO_4 and duration for delinating. The number of linters remaining on cottonseed after ginning is dependent upon both the type of gin used and the variety of cotton (Kanawade and Kashyap, 1981).

Table 2. Delinting efficiency (%) of sulfuric acid to remove lint from fuzzy cotton seeds.

		Time				
		4min	8min	12min	16min	Mean
H_4SO_4	60ml	13.91^{s}	15.80^{r}	20.69^{q}	23.39^{p}	18.45
	90ml	29.09^{o}	35.94^{n}	39.92^{m}	43.35^{l}	37.08
	120ml	46.57^{k}	52.51^{j}	57.94i	66.93^{h}	55.9893
	150ml	74.85^{g}	79.78^{f}	92.21^{e}	94.14^{d}	85.25
	180ml	98.93^{c}	99.39^{b}	99.97^{ab}	100.00^{a}	99.5756
	Mean	52.672	56.6875	62.152	65.5645	
SEm ±	3.54					
$LSD_{0.01}$	57.51					
CV(%)	1.10					

4.2. Germination Efficiency

The effect of sulfuric acid, used for removing lint from Deltapine 90 cotton variety fuzzy seeds, on germination is presented in Table 3. The analysis revealed highly significant differences ($P<0.01$) in germination percentage between and among control and other treatments consisting of different amounts of sulfuric acid and duration of delinting. Maximum germination (94%) was observed in treatment wherein fuzzy seeds had been treated with 150mL/kg of sulfuric acid delinted for 12min and further increase in either amount of sulfuric acid or delinting duration had no additional enhancement in germination. Thus, the efficiency of germination began to stabilize around maximum germination values already achieved, with no further effect of any of the other elevated treatments after 150mL/1kg of sulfuric acid. As for the range of germination obtained in various treatments, mean value of the maximum germination percentage (94%) was recorded in treatment T_{16}. This might be due to better delinting coupled with removal of light, immature and small seeds during delinting and rapid absorption of moisture as a result of increased permeability of seed coat. The minimum germination percentage (79%) was observed in control (T_1) which had fuzzy seeds. The decrease in germination with lower concentration of H_2SO_4 was due to the incomplete removal of fuzz from the seed coat. Previous study by (Anonymous 2009) on Desi cotton variety the dosage of 90 mL of H_2SO_4 mL/1kg of cotton seed recorded significantly higher seed germination (94.8%). The previous result on Desi cotton variety shows that amount of sulfuric acid and duration.

Table 3. Effect of delinting cotton seed on germination efficiency

		Time				
		4min	8min	12min	16min	Mean
H_4SO_4	60ml	81.00^{gh}	81.50^{fgh}	81.50^{fgh}	82.00^{fg}	81.5
	90ml	82.5^{efg}	83.50^{defg}	83.50^{defg}	84.00^{def}	83.375
	120ml	85.250^{cde}	85.50^{cd}	86.00^{cd}	87.50^{c}	86.125
	150ml	90.50^{b}	92.25^{ab}	94.00^{a}	92.75^{ab}	92.375
	180ml	93.00^{ab}	92.75^{ab}	92.25^{ab}	91.50^{ab}	92.375
	Mean	86.5	87.1	87.45	87.55	
SEm ±	0.56					
LSD	**					
CV(%)	5.93					

4.3. Normal Seedling

As described in section 3.5.2.1(a) under "Materials and Methods" germinated seeds were classified as normal or abnormal seedling. The analysis revealed highly significant differences ($P<0.01$) among various treatments in respect to normal seedling percentage due to different amount of sulfuric acid and duration of delinting time (Table 3). Maximum normal seedling emergence and development was observed in treatment 150mL/kg of sulfuric acid delinted for 12min. Regarding mean values of these characteristics, the maximum normal seedling percentage (88.75%) was recorded in treatment T_{16} whereas; the minimum was 66% in control (T_1). Interestingly, sulfuric acid delinting treatment decreased the percentage of abnormal seedlings bringing it down to 5.25% in treatment T_{17} in contrast to 13% in control treatment, i.e. seeds with fuzz. With regard to sulfuric acid delinting treatment, the results of this study agrees with the findings of (Sharma *et al*., 1976) which also revealed that acid delinting facilitates separation of immature, insect and disease affected seeds, thus upgrading the seed quality.

Table 4. Effect of delinting cotton seed on normal seedling

		Time				
		4min	8min	12min	16min	Mean
H_4SO_4	60ml	68.50^{ij}	70.25^{hi}	70.50^{hi}	72.25^{gh}	70.375
	90ml	73.00^{fgh}	74.00^{efg}	74.00^{efg}	74.50^{efg}	73.875
	120ml	74.00^{efg}	76.00^{ef}	76.00^{ef}	77.00^{e}	75.750
	150ml	82.25^{cd}	85.25^{bc}	88.75^{a}	85.75^{ab}	85.500
	180ml	85.00^{bc}	84.00^{bcd}	82.25^{cd}	81.50^{d}	83.187
	Mean	83.187	82.734	82.312	82.343	
SEm ±	0.72					
$LSD_{0.05}$	**					
CV(%)	3.16					

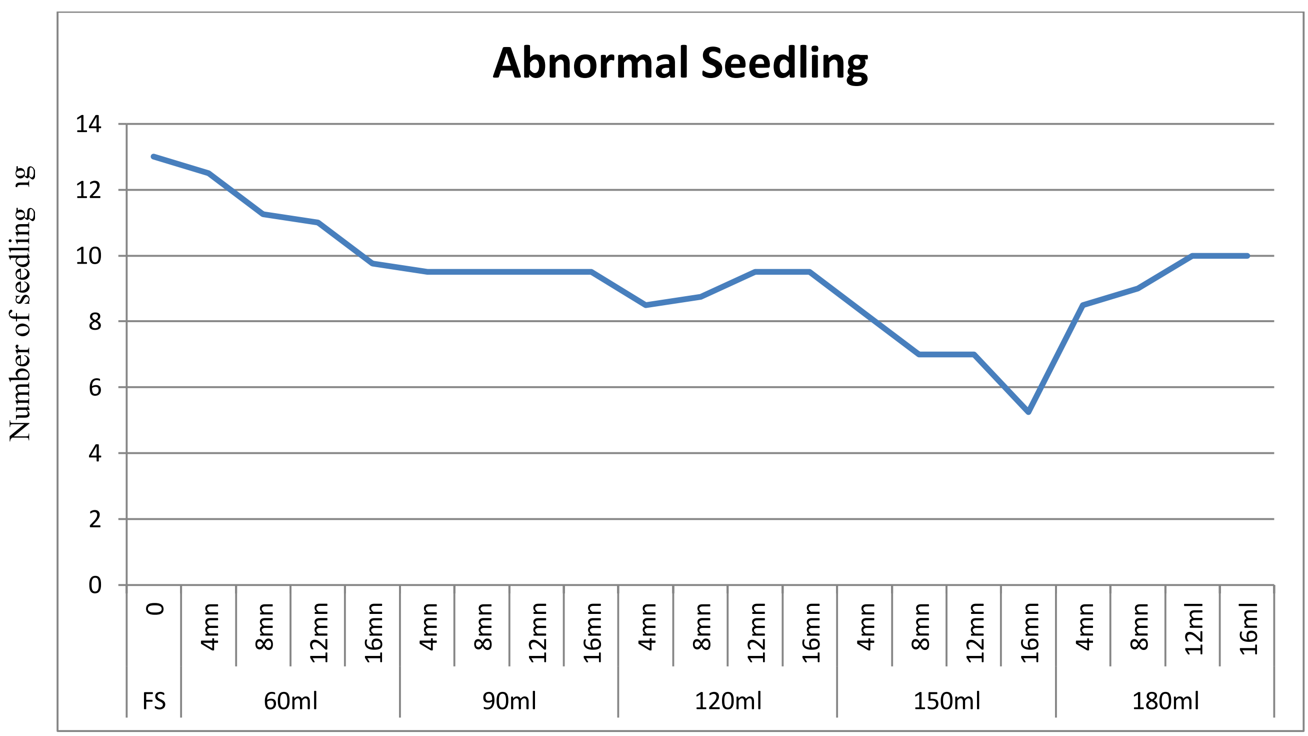

Figure 1. Abnormal seedling

4.4. Germination Speed Index-I

The effect of cotton seed deliniting by sulfuric acid on mean germination time (MGT) is presented in Table 3. The GRI reflects the percentage of germination on each day of the germination period. Higher GRI values indicate higher and faster germination (Esechie 1994). The analysis revealed highly significant differences ($P < 0.01$) due to different amounts of sulfuric acid and duration of delinting fuzz cotton seeds. The early germination time on higher germination value that is 728.5 on treatment of fuzzy seeds with 180mL/1kg delinted for 16min. However, longer time was on 292.25 germination value taken to germinate by seeds with fuzz present on seeds, i.e. control (T_1) which took almost nine days. Similarly, (Marani and Amirav 1970) stated that acid delinting improved and accelerated germination and emergence by increasing the permeability of the seed coat. Delaying seed germination suggests that lint might have interfered with the absorption of moisture on fuzz or partially removed lint cotton seeds.

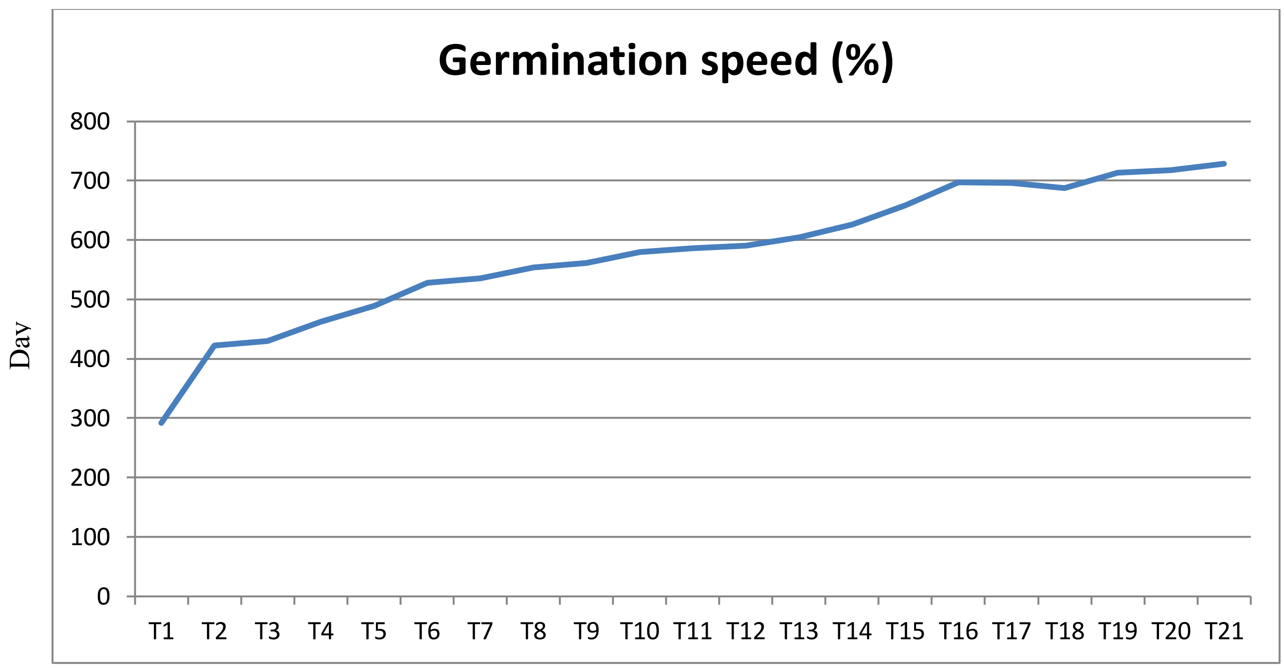

Figure 2. Germination speed

4.5. Germination Speed Index-II

Germination index or germination rate (GR) which indicates the number of seeds emerged but at the same time, it also shows the uniformity of seed germination. The results presented in Table 3 indicate that the delinted seeds by sulfuric acid had significantly higher germination rates. The maximum rate of 20.2% was observed in treatment T_{21}, i.e.180mL/1kg delinting for 16min which was statistically at par with those of T_{19} (19.6%) and T_{20} (19.9) and the minimum germination rate of 8.7% was observed in control (T_1). The effects of other treatments were found to range between 10.7% to 18.8%, reflecting on the increasing orders of amount of sulfuric acid and delinting duration combined, respectively. Similarly, (Patil and Andrews, 1985) reported the decrease in germination rate with lower concentration of H_2SO_4 was due to the incomplete removal of fuzz from the seed coat, which intern would slowed down the seed germination and seedling growth, because of low absorption of moisture by the seed coat.

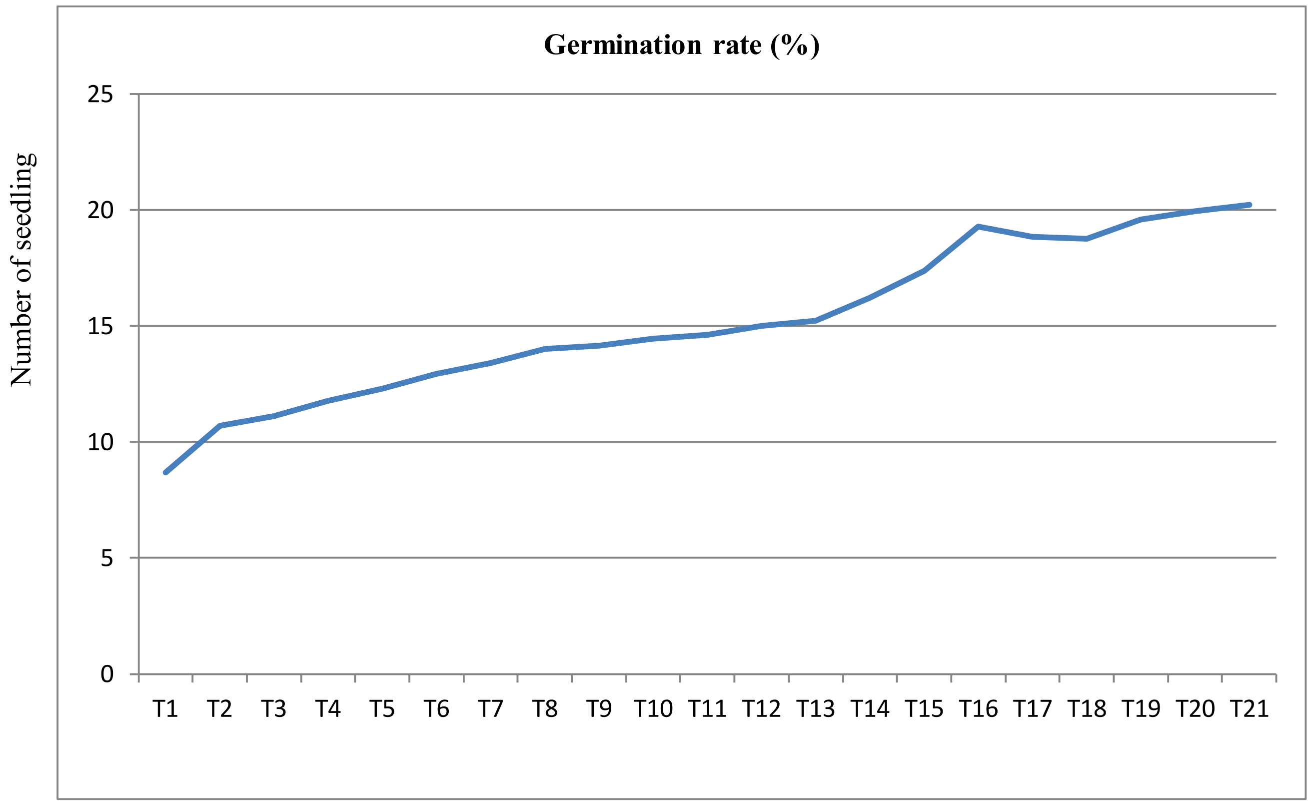

Figure 3. Germination rate

Table 5. Different amount of sulfuric acid and delinting duration effect on germination.

Treatment	Germination (%)	Normal seedling (%)	Abnormal seedling (%)	Germination rate (%)	Germination speed (%)
T_1	79.00^{h}	66.00^{j}	13.00^{a}	8.677^{m}	292.25^{o}
T_2	81.00^{gh}	68.50^{ij}	12.50^{a}	10.712^{l}	422.50^{n}
T_3	81.50^{fgh}	70.25^{hi}	11.25^{b}	11.117^{l}	430.25^{n}
T_4	81.50^{fgh}	70.50^{hi}	11.00^{bc}	11.782^{k}	462.75^{m}
T_5	82.00^{fg}	72.25^{gh}	9.75^{d}	12.290^{k}	489.00^{l}
T_6	82.5^{efg}	73.00^{fgh}	9.50^{de}	12.950^{j}	528.50^{k}
T_7	83.50^{defg}	74.00^{efg}	9.50^{de}	13.405^{ij}	535.75^{jk}
T_8	83.50^{defg}	74.00^{efg}	9.50^{de}	14.012^{hi}	554.00^{ij}
T_9	84.00^{def}	74.50^{efg}	9.50^{de}	14.162^{h}	561.75^{hi}
T_{10}	85.250^{cde}	74.00^{efg}	9.00^{def}	14.462^{gh}	580.25^{gh}
T_{11}	85.50^{cd}	76.00^{ef}	8.50^{efg}	14.632^{fgh}	586.00^{fg}
T_{12}	86.00^{cd}	76.00^{ef}	8.25^{fg}	15.010^{gf}	590.50^{fg}
T_{13}	87.50^{c}	77.00^{e}	8.00^{fgh}	15.225^{f}	605.00^{f}
T_{14}	90.50^{b}	82.25^{cd}	7.25^{gh}	16.220^{e}	626.75^{e}
T_{15}	92.25^{ab}	85.25^{bc}	7.00^{h}	17.397^{d}	658.75^{d}
T_{16}	94.00^{a}	88.75^{a}	5.25^{i}	19.290^{bc}	687.75^{c}
T_{17}	92.75^{ab}	85.75^{ab}	7.00^{h}	18.855^{c}	696.25^{bc}
T_{18}	93.00^{ab}	85.00^{bc}	8.50^{efg}	18.760^{c}	697.5^{bc}
T_{19}	92.75^{ab}	84.00^{bcd}	9.00^{def}	19.600^{ab}	713.25^{b}
T_{20}	92.25^{ab}	82.25^{cd}	10.00^{cd}	19.945^{a}	718.75^{a}
T_{21}	91.50^{ab}	81.50^{d}	10.00^{cd}	20.215^{a}	728.5^{a}
Sig. difference	**	**	**	**	**
CV (%)	2.05	2.31	0.00	2.19	2.00
SE±	0.56	0.72	0.21	0.36	12.44

Sig. difference= Significant difference ($P<0.01$), SE= Standard error, CV= Coefficient of variation
Observations superscripted with same letter are not statistically different.

4.6. Seedling Vigor Testing Systems

Seedling vigor is indicative of overall seedling growth which is determined by both inclusive of total shoot and root length and their dry weight. Therefore, these two aspects were studied in order to know the effects of various amounts and delinting durations of sulfuric acid treatment on Deltapine 90 fuzzy cotton seeds. It was found that seedling growth improved by the removal of lint from the seeds by sulfuric acid which, in turn, indicated invigorated seedling vigor. The results of the effect of sulfuric acid-caused removal of lint from fuzzy cotton seeds on seedling vigor index are presented in Table 4.

4.6.1. Seedling Vigor Index-I

The results presented in Table 4 clearly indicate that the maximum root length (9.25cm) was achieved under treatment having 150mL/kg of sulfuric acid for 12min of seed delinting treatment (T_{16}) whereas, the minimum root length (5.8cm) was observed under control treatment (T_1) which was fuzzy seeds, with differences being highly significant ($P<0.01$).Coincidently, shoot length was also maximum (9.6cm) under the same treatment (T_{16}) as observed for maximum root length growth. Once again, the minimum shoot length (6.2cm) was observed in control treatment (T_1). These data, when computed for seedling vigor index-I (SVI-I) revealed its highest value (1673.43) in treatment T_{16} and the lowest (668.14) under treatment T_1 (control). A similar study conducted by (Anonymous 2009) indicate that on Desi cotton variety higher seedling vigour index (1077) with the dosage of 80mL and 90mL H_2SO_4 for delinted 8 min, the other study carried out by (Singh *et al*., 1981) on cotton variety MCU 5, 200mL/kg resulted in maximum seedling vigor delinit fuzz cotton seeds. Amounts of sulfuric acid higher or lower than 150mL/kg decreased seedling vigor index-I but the values so-obtained were still higher under former conditions than those under latter ones. Apparently, improvement in growth attributes must have been due to removal of lint which facilitated the early vigor seed germination. Vigor index increased with increase in acid quantity and delinting time to certain level and thereafter started declining. It showed that up to certain quantity time to certain level and thereafter started declining (Javellonar et al., 1998).

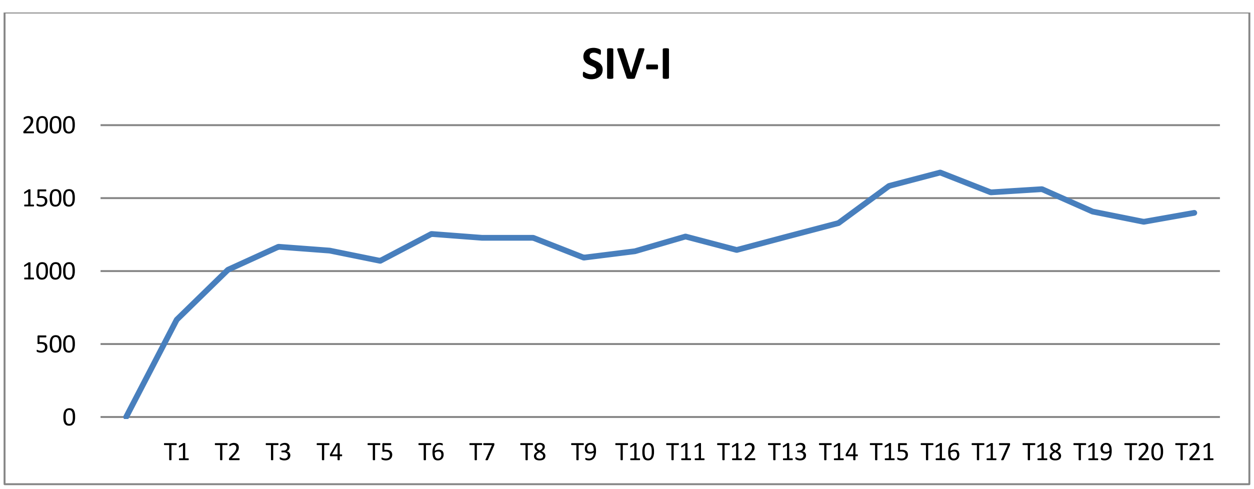

Figure 4. Seedling Vigor Index-I

4.6.2. Seedling vigor index-II

Delinting seeds treatment by sulfuric acid was also found to have significant effect ($p<0.01$) on dry weight of shoot such that the maximum seedling dry weight (0.5025g) was observed under treatment T_{16} while, the smallest seedling dry weight (0.3425g) was recorded under control treatment T_1. As a result, seedling vigor index-II (SVI-II) was highest (44.16) under treatment $T_{16}$with smallest being 21.643 under treatment T_1 (control). High concentration of acid caused more injury and reduced seedling dry mass and germination (Onkarsingh et al. 1983). Delinated seeds more efficiently mobilize reserves from storage tissues to the embryo axis and this capacity is reflected in seedling growth. Vigor index increased with increase in acid quantity and delinting time to certain level and thereafter started declining. It showed that up to certain quantity time to certain level and thereafter started declining.

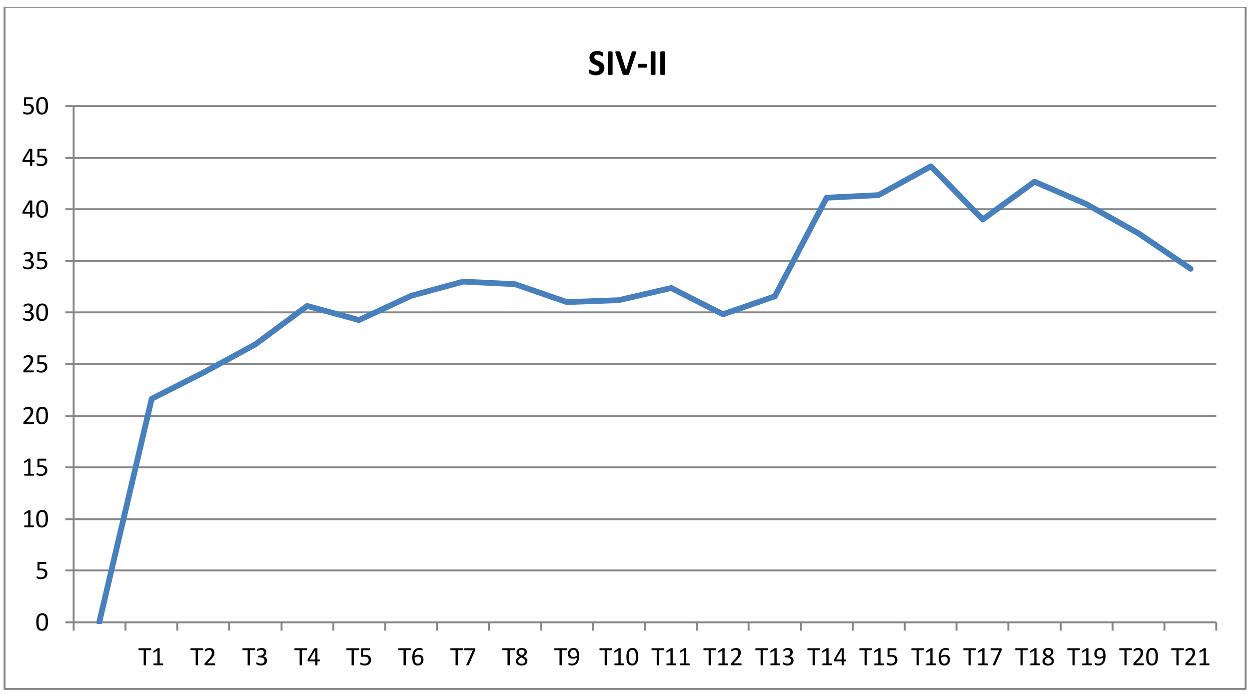

Figure 5. Seedling Vigor Index-II

Table 6. Cotton seedling vigor and its attributes as affected by amount and duration delinting of sulfuric acid and.

Treatments	Root length (cm)	Shoot length (cm)	Dry weight (g)	SIV-I	SIV-II
T_1	5.800^{l}	6.200^{l}	0.3425^{m}	668.14^{i}	21.643^{k}
T_2	7.350^{ghi}	7.377^{k}	0.3775^{l}	1008.29^{h}	24.190^{jk}
T_3	8.312^{cd}	8.350^{hij}	0.4050^{k}	1168.19^{efg}	26.915^{ij}
T_4	7.500^{efgh}	8.675^{fghi}	0.4250^{ghij}	1140.33^{fg}	30.670^{fgh}
T_5	6.650^{ijk}	8.175^{j}	0.4325^{fghi}	1070.63^{gh}	29.255^{hi}
T_6	8.537^{bc}	8.412^{ghij}	0.4150^{jk}	1254.26^{de}	31.615^{efh}
T_7	8.012^{cdef}	8.500^{ghij}	0.4175^{ijk}	1229.14^{def}	32.978^{ef}
T_8	7.925^{cdefg}	8.707^{fgh}	0.4350^{fgh}	1229.27^{def}	32.740^{ef}
T_9	6.612^{jk}	8.337^{i}	0.4375^{fg}	1091.50^{gh}	31.033^{fgh}
T_{10}	6.250^{kl}	8.687^{fghi}	0.4425^{ef}	1135.35^{fg}	31.180^{fgh}
T_{11}	7.700^{defgh}	9.025^{def}	0.4200^{hijk}	1237.50^{def}	32.370^{efg}
T_{12}	7.200^{hij}	8.750^{efg}	0.4675^{cd}	1145.63^{efg}	29.848^{gh}
T_{13}	7.925^{cdefg}	9.037^{cdef}	0.4375^{fg}	1237.68^{def}	31.580^{efgh}
T_{14}	7.250^{hij}	8.925^{def}	0.4275^{fghij}	1330.46^{cd}	41.125^{bc}
T_{15}	9.112^{ab}	9.465^{ab}	0.4550^{de}	1582.98^{ab}	41.373^{abc}
T_{16}	9.250^{a}	9.602^{a}	0.5025^{a}	1673.43^{a}	44.160^{a}
T_{17}	8.537^{bc}	9.400^{abc}	0.4750^{c}	1538.26^{b}	39.020^{cd}
T_{18}	9.150^{ab}	9.212^{bcd}	0.4950^{ab}	1560.84^{b}	42.695^{ab}
T_{19}	7.637^{defgh}	9.112^{bcde}	0.4825^{bc}	1407.84^{c}	40.533^{bc}
T_{20}	7.150^{hij}	9.100^{bcde}	0.4750^{c}	1336.58^{cd}	37.635^{d}
T_{21}	8.187^{cde}	9.000^{def}	0.4575^{de}	1400.69^{c}	34.248^{e}
Sig. difference	**	**	**	**	**
CV (%)	2.37	3.41	2.07	4.37	4.04
SE±	0.18	0.29	0.01	26.08	1.37

Sig. difference= Significant difference (P<0.01), SE= Standard error, CV= Coefficient of variation
Observations superscripted with same letter are not statistically different at 1% level.

4.7 Correlation Matrix of Entire Delinting Process of Fuzzy Cotton Seeds

Correlation matrices of entire delinting process of fuzzy cotton seeds and seedling vigor as affected by different amount and duration of sulfuric acid in terms of germination efficiency and seedling vigor parameters were statistically worked out and fuzz cotton seeds delinting by sulfuric acid was significantly related to most of attributes of germination efficiency parameters (Table5). Delinted Deltapine 90 cotton variety was positively correlated and highly significant with germination efficiency ($r = 0.914^{**}$), normal seedling ($r = 0.845^{**}$), germination speed ($r =-0.946^{**}$) which is shortened germination period, germination rate ($r = 0.979^{**}$), root length ($r = 0.443^{**}$), shoot length ($r = 0.760^{**}$), seedling dry weight ($r = 0.833^{**}$) and seedling vigor index I and II (r= 0.824** and 900** respectively). This might be due to better delinting coupled with removal of light, immature and small seeds during delinting and rapid absorption of moisture as a result of increased permeability of seed coat (Hiwase *et al.,* 1994).

Whereas, delinted Deltapine 90 cotton variety showed a highly significant negative correlation (r= -0.606**) of seedling abnormality. This might be higher doses of H_2SO_4 and longer time delinted seeds may damage the seed coat. It shows that up to certain quantity of acid and exposing time, the acid action causes removal and dissolution of the lint sticking on seed coat and further rise in acid quantity and exposing time, the action causes seed coat damage and embryo death.

Table 7. Correlation matrix of various parameters

	SAE	GE	NS	AS	GS	GR	SDW	SVI-I	SVI-II
SAE	1.000								
GE	0.918**	1.000							
NS	0.895**	0.957**	1.000						
AS	-0.625**	-0.634**	-0.746**	1.000					
GS	0.957**	0.865**	0.858**	0.608**	1.000				
GR	0.978**	0.894**	0.880**	-0.612**	0.978**	1.000			
SDW	0.048ns	0.030ns	0.041ns	0.137 ns	-0.030ns	0.103ns	1.000		
SVI-I	0.562**	0.547**	0.555**	-0.409**	0.554**	0.538**	0.345*	1.000	
SVI-II	0.642**	0.678**	0.685**	-0.454**	0.550**	0.603**	0.271*	0.795**	1.000

**Highly significant different, * Significant different, ns = Non-significant difference; SAE=Sulfuric acid efficiency, GE=Germination efficiency, NS=Normal seedling, AS=Abnormal seedling, GS=Germination speed, GR= Germination rate, SDW=Seedling dry weight, SVI-I= Seedling vigor index-I; SVI-II= Seedling vigor index-II

5. SUMMARY AND CONCLUSION

5.1. Summary

The cotton seeds obtained from ginneries contain about 8 to 10% of lint (fuzzy seed), which make them clamp together during sowing. Presence of fuzz on the seeds coat of cotton makes it difficult to remove the damaged, diseased and immature seeds during grading. This renders them inappropriate for planting manually or by machine, enables floaters difficult to separate from sinkers and after sowing deprives of moisture absorption by seeds which causes delayed germination and results in poor germination. Enabling easy flowing characteristics of the seeds and also upgrading seed quality are necessary components of successful cotton cultivation. Fuzz cotton seed delinting by sulfuric acid is one of the techniques that not only removes the lint but improves seed performance as well by rapid and uniform germination leading to normal, healthy and vigorous seedlings. However, optimum amount and delinting duration with sulfuric acid standardizing the dosage of H_2SO_4 and duration for delinting of Deltapine 90 variety cotton seeds have not been studied before in Ethiopian.

Therefore, in order to study the effect of sulfuric acid amount and delinting duration on delinting efficiency, germination percentage, and seedling vigor of Deltapine 90 cotton (*Gossypium hirsutum* L.) seeds, experiments adopting completely randomized design (CRD) were conducted at the Gondar Seed Laboratory. The main factors of the experiments included Deltapine-90 cotton variety fuzz seeds delinting by five different quantities of 98% concentrated sulfuric acid (60mL, 90mL, 120mL, 150mL and 180mL/kg seeds). Exposing of the seeds to the acid with these amounts of sulfuric acid for four different durations of time (4min, 8min, 12min and 16min) with the fuzz cotton seeds considered as control (untreated) treatment. Based on all the treatments, there were 21 treatment combinations replicated four times.

5.2. Conclusion

Results indicate that removing lint from cotton seeds by sulfuric acid was highly positively correlated with the amount of sulfuric acid used. Observations revealed that some seeds did freely flow when treated with 90mL/kg of sulfuric acid and delinted for 8min (35.9%) whose numbers increased (100%) when delinted by 180mL H_2SO_4 for 16min. It shows that up to certain quantity of acid and exposing time, the acid action causes removal and dissolution of the lint sticking on seed coat and further rise in acid quantity and exposing time, the action causes seed coat damage and embryo death.

All the seed treatments improved final germination percentage (FGP) with significant differences among treatments as compared to control. The maximum germination (94%) and normal seedling growth (88.7%) were recorded following delinting fuzz cotton seeds treated by 150mL of sulfuric acid for 12min and the minimum germination (79%) with normal seedling development (66%) was observed in control (T_1) having fuzzy seeds. This might be due to better delinting coupled with removal of light, immature and small seeds during delinting and rapid absorption of moisture as a result of increased permeability of seed coat.

As for speed of germination, early germination which took only 5 days was recorded under delinting treatment of 180mL for 16min with delayed germination taking 9 days under control treatment suggesting that lint might have interfered with the absorption of moisture by germinating seeds. Seedling vigor was related to earliness of germination. Further, delinting in all cases improved seedling vigor resulting from increased shoot and root length as well as enhanced seedling dry weight as compared to fuzzy seeds. However, seedling vigor index increased with increase in acid quantity and delinting time to certain level (150mL for 12min) and thereafter started declining.

On the basis of the results obtained, it was concluded that seed delinting by 150mL of sulfuric acid per one kg of fuzzy seeds for 12min was most effective and significantly enhanced the germination and early seedling growth of cotton variety Deltapine-90 compared to undelinted seeds. Treatment combinations other than that mentioned above, gave in general the intermediate responses. It is of significance that free flow of seeds for easy sowing manually or by machine is facilitated by delinting which otherwise is impossible to achieve by fuzz cotton seeds. It was further noted that as the efficiency of delinting increased with the increase in the amount of sulfuric acid (positive correlation) up to 150mL/1kg of fuzz seeds but with further increase in amount and delinting duration, the abnormal seedlings started to increase and the efficiency of germination dropped either. Seedling growth has also improved by seed delinting which, in turn, invigorated general seedling vigor on account of higher root and shoot length and seedling dry weight scaling up both of seedling vigor index one and two.

Apparently, improvement in growth attributes must have been due to removal of lint which facilitated the early vigor seed germination. It is therefore, concluded that removing lint by using optimum amount of sulfuric acid (150mL/kg fuzz seeds) for appropriate delinting duration (12min) can make the sowing easy due to free flowable seeds and improves germination efficiency; enhances speed of germination, germination rate, and seedling vigor of planting cotton seeds. However, further different fuzz cotton seed delinting techniques should also be studied to deliver alternatives, if possible, to farmers and investors.

6. RECOMMENDATION

To improve free flow during sowing of planting fuzz cotton seeds for uniform and early germination and enhanced germination efficiency, removing lint from the seeds is the main activity of cotton growers. Better delinting coupled with removal of light, immature and small seeds during delinting and rapid absorption of moisture as a result of increased permeability of seed coat was achieved by sulfuric acid treatment. So, based on the findings of this study using 150mL of 98% concentrated sulfuric acid for each 1kg of fuzzy Deltapine-90 cotton seeds treated and exposed for 12min of delinting duration is recommended for the time being for overall better performance of cotton crop as it has resulted in enhanced free flow of seeds, early and uniform emergence of seedlings, improved germination and seedling vigor taking precaution to reduce the risk of the acid. However, as the study was conducted only for one time, it should be repeated using the same or modified treatments to arrive at concrete recommendation.

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8. APPENDIX

Appendix Table 1. Sulfuric acid delinting efficiency

Treatment Code	Treatments	Dry weight of fuzzy seeds(gm)	Dry weight of delinted seeds	Sulfuric acid delinting Efficiency (%)
T_1	Untreated seed(fuzzy seed)	100.00	-	0.00
T_2	60ml H_2SO_4 for 1kg delinitig for 4min	100.00	98.07	13.79
T_3	60ml H_2SO_4 for 1kg delinitig for 8min	100.00	97.79	15.79
T_4	60ml H_2SO_4 for 1kg delinitig for 12min	100.00	97.52	17.71
T_5	60ml H_2SO_4 for 1kg delinitig for 16min	100.00	97.41	18.50
T_6	90ml H_2SO_4 for 1kg delinitig for 4min	100.00	95.97	28.79
T_7	90ml H_2SO_4 for 1kg delinitig for 8min	100.00	94.87	36.64
T_8	90ml H_2SO_4 for 1kg delinitig for 12min	100.00	94.47	39.50
T_9	90ml H_2SO_4 for 1kg delinitig for 16min	100.00	93.94	43.29
T_{10}	120ml H_2SO_4 for 1kg delinitig for 4min	100.00	93.84	44.00
T_{11}	120ml H_2SO_4 for 1kg delinitig for 8min	100.00	92.71	52.07
T_{12}	120ml H_2SO_4 for 1kg delinitig for 12min	100.00	91.63	59.79
T_{13}	120ml H_2SO_4 for 1kg delinitig for 16min	100.00	90.92	64.86
T_{14}	150ml H_2SO_4 for 1kg delinitig for 4min	100.00	89.43	75.50
T_{15}	150ml H_2SO_4 for 1kg delinitig for 8min	100.00	88.46	82.43
T_{16}	150ml H_2SO_4 for 1kg delinitig for 12min	100.00	86. 94	93.29
T_{17}	150ml H_2SO_4 for 1kg delinitig for 16min	100.00	86. 84	94.07
T_{18}	180ml H_2SO_4 for 1kg delinitig for 4min	100.00	86. 15	98.93
T_{19}	180ml H_2SO_4 for 1kg delinitig for 8min	100.00	86.09	99.36
T_{20}	180ml H_2SO_4 for 1kg delinitig for 12min	100.00	86.04	99.71
T_{21}	180ml H_2SO_4 for 1kg delinitig for 16min	100.00	86.00	100

$$\text{DelintingEfficiency}(\%) = \frac{\text{Dryweight of fuzzy seeds} - \text{Dry weight of delinted seeds}}{\text{Dryweightoffuzzyseeds} - \text{Dry weight of last constant delinted seeds}} \text{ X } 100$$

Calculate by using 86 as a last constant dry weight of delinted seeds.

Appendix Table 2. Mean squares of sulfuric acid efficiency, germination efficiency, speed and rate, normal and abnormal seedling, seedling dry weight, SVI I and II of cotton.

Source	DF	Mean squares								
		SAE	GE	NS	AS	GS	GR	SDW	SVI-I	SVI-II
Treat.	20	4371.13**	96.65**	165.05**	13.26**	52978.55**	45.36**	3.67**	50961.88**	64.53**
Rep.	3	0.69ns	5.92ns	14.14ns	3.70*	2731.85**	2.53**	0.87*	16012ns	3.03ns
Error	60	0.39	4.12	5.98	0.77	203.13	0.21	0.27	8329.8	5.09
Total	83									
CV (%)		1.10	2.34	3.17	9.50	2.46	2.99	6.86	7.19	6.75
R^2 (%)		1.00	0.89	0.90	0.86	0.99	0.99	0.82	0.68	0.81

Appendix Figure 1. Main materials for this research (sulfuric acid and fuzzy cotton seeds)

Appendix Figure 2. Sowing media for cotton seeds germination.

Appendix Figure 3. Sulfuric acid delinting efficiency.

Appendix Figure 4. Seedlings performance from variously sulfuric acid-treated seeds.

Appendix Figure 5. Germination and seedling growth and vigority on delinated cotton seed.

Appendix Figure 6. Germination efficiency variously sulfuric acid-treated seeds.

Appendix Figure 7. Evaluation of cotton seedling with different treatments.